Application of the TDS Technique in Gas Reservoirs

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ABSTRACT

Tiab's Direct Synthesis (TDS) is a direct technique to interpret transit well pressure tests. It is analysis of pressure and pressure derivative without type-curve matching. This method uses log-log Plot of the pressure and pressure derivative versus time to compute reservoir parameters such as permeability, wellbore storage, skin factor, and average reservoir pressure.
The main objective of this study is to apply TDS technique for gas reservoirs "long test", and show the advantage of TDS technique, where this technique is particularly useful when the late-time infinite acting radial flow is not observed, which is called "short test".
Two cases are presented in the study to analyze pressure data using TDS technique, a build -up test is conducted on the well (4U11) from Faregh field and well (5A5) from Gialo field.
Based on the results and comparing between the long and short test; the results were converged, which indicates that TDS can be used if some flow regimes are not available. The technique is useful method for analyzing pressure test.

Keywords: TDS technique, Pressure, Derivative, Wellbore storage.

1 Introduction

One of problem in pressure derivative on log-log plot that the radial flow region is not observed, TDS solved this issue by analyzing well bore storage region and read direct specific values from the plot substituting in equations to determinate parameters that cannot be estimated from radial flow such like permeability, and skin this advantage is called (Short test) [1] . Another problem faced in this paper, the huge raw data from DST test, which takes reading for pressure every ten seconds, solving this problem comes with filtering or screening the best build up region to be fit and clear enough for TDS calculations.
The objective of this paper is to analysze pressure transient in gas reservoirs using Tiab's direct synthesis method and use advantage of this technique to determine reservoir properties

2 Methodology

The pressure test data was collected and screened by using Kappa software. Then the pressure data was analyzed by TDS technique using Excel software.

2.1 TDS technique

Direct synthesis method uses a log-log plot of pressure and pressure derivative data versus time to calculate various reservoirs and well parameters. The technique uses the pressure derivative technique to identify reservoir heterogeneities. In this method, the values of the slopes, intersection points, and beginning and ending times of various straight lines from the log-log plot can be used in exact analytical equations to calculate different parameters [2, 3].

TDS technique procedure

In this paper, TDS technique uses to analyze pressure test data in two cases as following;

- **The wellbore storage and infinite acting radial flow is observed (Long test):**

The following steps are presented with greater detail in Tiab [1, 3].

Step 1- Converting pressure data (P) to real gas pseudo pressure data m(P) to linearize the gas diffusivity equation.

$$m(P)i = \left(\frac{2P}{\mu Z}\right) i^{*} + m(P)_{i} \tag{1}$$

Step 2- Calculate Δm(P) and Δt using the following equation:

$$\Delta m(P) = m(P)i - m(P) \tag{2}$$

Step 3- Calculate Derivative of each values using equation:

$$t \times \Delta m(P)' = \Delta t \times \left(\frac{\Delta m(P)_{i+1} - \Delta m(P)_{i-1}}{(\Delta t)_{i+1} - (\Delta t)_{i-1}}\right) \tag{3}$$

Step 4-Plot Δm(P) and t×Δm(P)' versus time in log-log graph.

Step 5- Draw the unit-slope line corresponding to the wellbore storage flow regime using early-time pseudo pressure and derivative points.

$$C = \left(\frac{0.42 q_{sc} T}{\mu i}\right)\left(\frac{t_N}{t \times \Delta m(P)_N{}'}\right) \tag{4}$$

Step 6- Draw the infinite acting radial flow line using late-time pseudo pressure derivative points. This line is horizontal.

Step 7-Read the coordinates of the infinite-acting horizontal line intersect this value is (t×Δm'(P)).

Step 8- Calculate permeability (K):

$$K = \frac{711.26 q_{sc} T}{h(t \times \Delta m'(P))} \tag{5}$$

Step 9- Calculate the total skin factor (S'): The skin factor is determined from a relationship between the pseudo pressure and its derivative during the infinite acting radial flow.

$$S' = S + Dq_{sc} = 0.5\left[\frac{(\Delta m(P))_R}{(t \times \Delta m'(P))_R} - ln\left(\frac{K t_R}{\emptyset(\mu C_t)i(r_w{}^2)}\right)\right] \tag{6}$$

Step 10- Calculate the average reservoir pressure:

First, calculate the average pseudo pressure using equation

$$m(\acute{P}) = m(pi) - 2((t\times\Delta m'(p))r\left[\left(\frac{(t\times\Delta m'(p))pss}{(\Delta m(p))pss - ((t\times\Delta m'(p))pss}\right)\left(ln\frac{re}{rw} - \frac{3}{4} + S'\right)\right] \tag{7}$$

Then using the equation from the relation between pressure (P) and pseudo pressure m(P) to calculate average reservoir pressure.

- **The infinite acting radial flow is not observed (Short test).**

The following procedures are applied if the pressure test is too short to observe the infinity acting radial flow or is not well defined. Therefore, it cannot read the value of $(t\times\Delta m'(P))_R$; because the horizontal line of the infinite acting radial flow is not observed.

Step 1- Plot Δm(P) and t×Δm(P)' versus time on a log-log graph .

Step 2- Read the value of t_x, and $t\times\Delta m'(P)_x$ from the log.log plot as shown in case study.

Step 3- Calculate $(t\times\Delta m'(P))_R$

$$\left(t \times \Delta m'(P)\right)R = \left(0.151\frac{qT}{\mu C}\right)t_x - \left(t \times \Delta m'(P)\right)x \tag{8}$$

The value of (t×Δm'(P))R, can be used to estimate the permeability if the infinite acting line is not available(short test) as shown in the case study .

Step 4- Calculate permeability (K) by using equation 5.

Step 5- Calculate total skin factor(S'): The skin factor is estimated from:

$$S' = 0.171\left(\frac{t_x}{t_{RiUS}}\right)^{1.24} - 0.5ln\left(\frac{0.8935C}{\emptyset h C_t r_w{}^2}\right) \tag{9}$$

3 Case Study

This paper presents two Libyan gas wells from different fields. These wells are well (4U11) in Gialo field and well (5A5) in Faregh field.

3.1 Case 1- Well (4U11)

Relevant information concerning well 4U11 reservoir and fluid is given in Table 1.

Table 1: *General information of Well (4U11)*

Field:	Gialo
Well:	4U11.
Well Radius(rw):	0.34 ft.
Drainage Area Radius(re):	745 ft.
Net Thickness(h):	31 ft.
Initial Pressure (Pi):	5250 Pisa.
Reservoir Temperature:	263°F.
Total Compressibility	1.074×10^{-4} psi-1
Gas viscosity(µg)	0.028 cp.
Specific gravity (γg)	0.69
Gas flow rate (qg)	15.807MMscf/D
Porosity (∅)	18

Step 1. Convert the pressure data (P) to m(P) using the equation 1, as shown in table 1.

Table 2: *Calculation of m(p) for Well (4U11).*

Pressure	Gas Z Factor	gas Viscosity	2p/z*µ	(2P/µz)m)	(2P/µz)m)*Δp	m(pi),psi²/cp
Pisa		cP	Psi/cp	Psi/cp	psi^2/cp	psi^2/cp
1000	0.911	0.015	146327.2	73163.59	7.32E+07	7.32E+07
1300	0.912	0.016	178101.7	162214.4	4.87E+07	1.22E+08
1700	0.915	0.017	218531.5	198316.6	7.93E+07	2.01E+08
2100	0.921	0.018	253430.4	235980.9	9.44E+07	2.96E+08
2600	0.924	0.020	281294	267362.2	1.34E+08	4.29E+08
3100	0.934	0.021	316202.3	298748.1	1.49E+08	5.79E+08
3700	0.939	0.024	328538.4	322370.4	1.93E+08	7.72E+08
4700	0.991	0.030	316242.8	322390.6	3.22E+08	1.09E+09
5228	1.036	0.034	296871.7	306557.2	1.62E+08	1.26E+09

Figure 1 is a linear plot of m(P) versus P. The equation of trend line is

$$y = 38.876x^2 + 150671x - 1E+08 \quad (10)$$

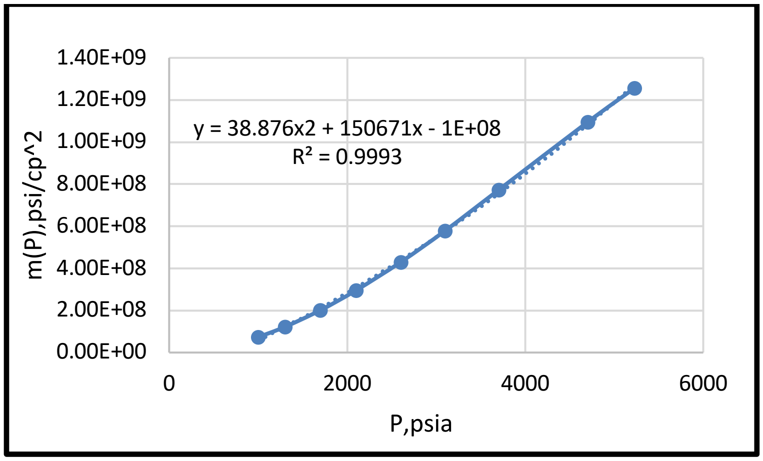

Figure 1: *Linear plot of P and m(P) for Well (4U11)*

By using equation 10, calculate the initial reservoir pressure:

y = (38.876×52502) + (150671×5250) – (1E+08) = 1.76×10^{9} psi^2/cp

Then, $m(P_i) = 1.76\times10^{9}$ psi^2/cp

After convert all pressure to pseudo pressure, calculate the Δm(P) using equation 2 and Δt. Then calculate the derivative of pseudo pressure by using equation 7.

3.1.1 Infinite acting radial flow line is observed (Long test) for well 4U11:

Draw the unit-slope line corresponding to the well bore storage flow regime as shown in figure 2, then calculate the well bore storage effect (C) by using equation 4.

$$C = \left(\frac{0.42\times15.807\times10^{3}\times(263+460)}{0.028}\right)\left(\frac{0.05}{2.85\times10^{8}}\right) = 0.03003 \text{ bbl/psi}$$

From a log-log plot of pseudo pressure versus time, figure 2, the infinite acting radial flow is observed at (t×Δm'(P)r =4×106 Psi2/cp (the coordinates of the infinite-acting horizontal line intersect) . The average permeability is computed by using equation 5.

$$K = \frac{711.26\times15.807\times10^{3}\times(263+460)}{31\times4\times10^{6}} = 6.55 \text{ md.}$$

From figure 2, read the values of t_R, and Δm(P) and calculate the total skin factor (S') by using the equation 6

$$S' = 0.5\left[\frac{1.72\times10^{9}}{4\times10^{6}} - ln\left(\frac{5.66\times1.666667}{0.18\times0.028\times1.074\times10^{-4}\times0.34^{2}}\right)\right]=15.64$$

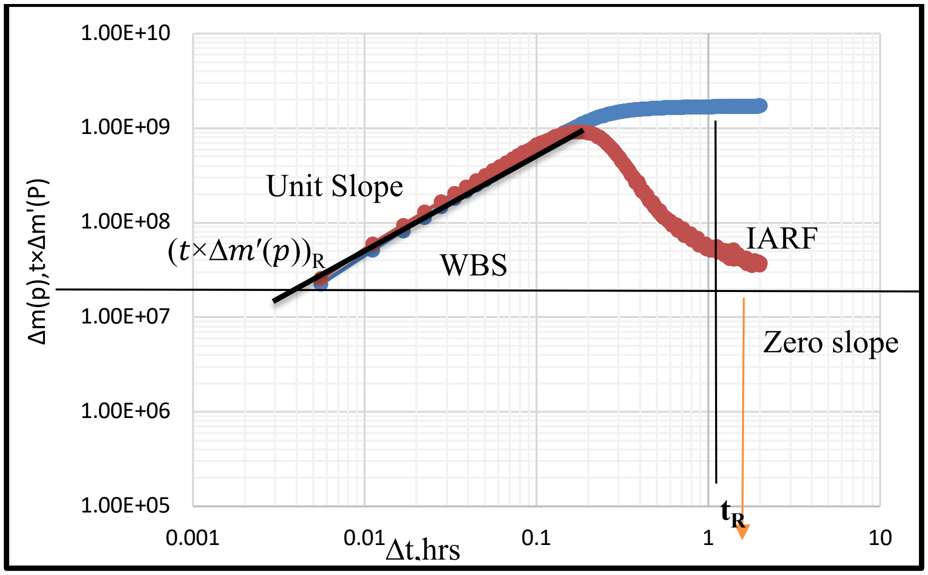

Figure 2: *Analysis of infinite acting radial flow for Well (4U11).*

3.1.2 Infinite acting radial flow line is not observed (short test) for Well (4U11):

In this case, the infinity acting radial flow line was cut to apply the analysis (short test) when infinite acting radial flow is not observed as shown in figure 3. From figure 3 read the value of tx, and (t×Δm'(P)x) and calculate $(t\times\Delta m'(P))_R$ using equation 8.

$$(t\times\Delta m'(P))R=\left(0.151\,\frac{15.807\times10^{3}\times(263+460)}{0.028\times0.03003}\right)\times0.3-5.01\times10^{8}=3.81\times10^{7}\ psi^{2}/cp.$$

Calculate the permeability from equation 5.

$$K=\frac{711.26\times15.807\times10^{3}\times(263+460)}{31\times3.81\times10^{6}}=6.88\ md.$$

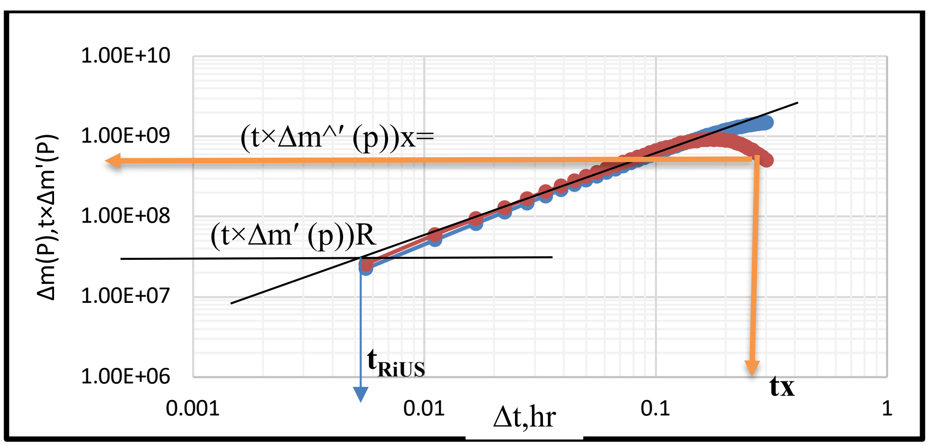

Figure 3: *Short test for Well (4U11).*

Read the value of tRiUS (tRiUS=0.0065 hrs.) from figure3. , then calculate total skin factor using equation 9.

$$S' = 0.171\left(\frac{0.3}{0.0065}\right)^{1.24} - 0.5ln\left(\frac{0.8935\times0.03003}{0.18\times31\times1.074\times10^{-4}\times0.34^2}\right)=16.75.$$

3.2 Case 2- Well (5A5)

Relevant information concerning well 5A5 reservoir and fluid is given in Table 3.

Table 3: *General information of Well (5A5)*

Field:	Faregh.
Well:	5A5.
Well Radius(rw):	0.34 ft.
Drainage Area Radius(re):	1500 ft.
Net Thickness(h):	33.5 ft.
Initial Pressure (Pi):	5100 psi.
Reservoir Temperature:	240 F.
Total Compressibility	1.13×10-4 psi-1.
Gas viscosity(μg)	0.0282 cp.
Specific gravity (γg)	0.6685
Gas flow rate (qg)	24.05 MMscf/D.
Porosity (Ø)	13.9.

Step 1. Convert the pressure data (P) to m(P) using the equation 1, the part of calculation is shown in table 4.

Table 4: *m(p) for Well (5A5).*

P,psi	m(P),psi2/cp
1014.7	7.49E+07
1064.7	8.23E+07
1114.7	9.01E+07
1164.7	9.82E+07
1214.7	1.07E+08
1264.7	1.15E+08
1314.7	1.24E+08
1364.7	1.34E+08
1414.7	1.43E+08
1464.7	1.53E+08
1514.7	1.64E+08
1564.7	1.74E+08
1614.7	1.85E+08
1664.7	1.96E+08

Figure 4 is a linear plot of m(P) versus P. The equation of trend line is

$$y = 37.513x^2 + 99041x - 7E+07 \qquad (11)$$

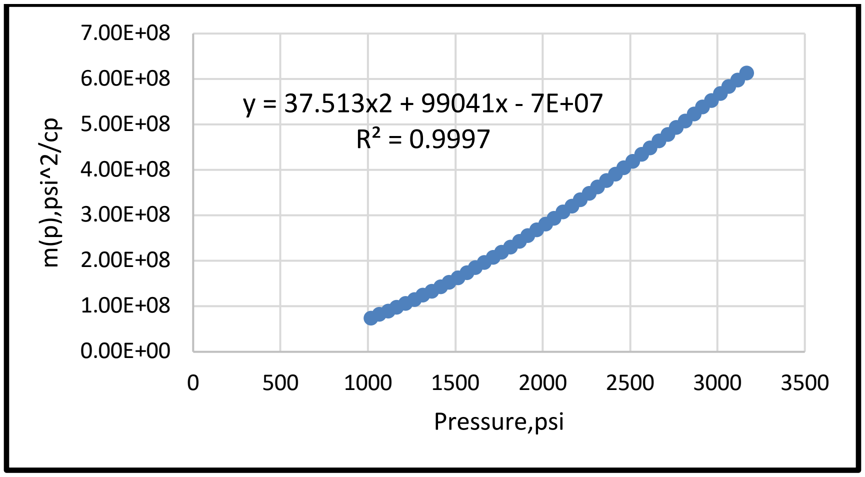

Figure 4: *Linear plot of P and m(P) for Well (5A5)*

By using equation 10, calculate the initial reservoir pressure:

y = (37.513×51002) + (99041×5250) – (7E+07) = 1.411×10^9 psi^2/cp

m(Pi)= 1.411×10^9 psi^2/cp

After convert all pressure to pseudo pressure, calculate the Δm(P) using equation 2 and Δt. Then calculate the derivative of pseudo pressure by using equation 7.

3.2.1 Infinite acting radial flow line is observed (Long test) for well 5A5:

After screening of (54143) data point, became (257) data point for analysis.

Draw the unit-slope line corresponding to the well bore storage flow regime as shown in figure 5, then calculate the well bore storage effect (C) by using equation 4.

$$C = \left(\frac{0.42\times24.05\times10^3\times(240+460)}{0.0282}\right)\left(\frac{0.025}{1.557\times10^8}\right) = 0.0402 \text{ bbl/psi}$$

From a log-log plot of pseudo pressure versus time, figure 5, the infinite acting radial flow is observed at (t×Δm'(P)r =2.68×10^7 Psi^2/cp.

(the coordinates of the infinite-acting horizontal line intersect) . The average permeability is computed by using equation 5.

$$K = \frac{711.26\times24.05\times10^3\times(240+460)}{33.5\times2.68\times10^7} = 13.33 \text{ md.}$$

From figure 5, read the values of t_R, and Δm(P) and calculate the total skin factor (S') by using the equation 6

$$S' = 0.5\left[\frac{4.08\times10^8}{2.68\times10^7} - ln\left(\frac{13.33\times0.35}{0.139\times0.0282\times1.13\times10^{-4}\times0.34^2}\right)\right] = 2.15$$

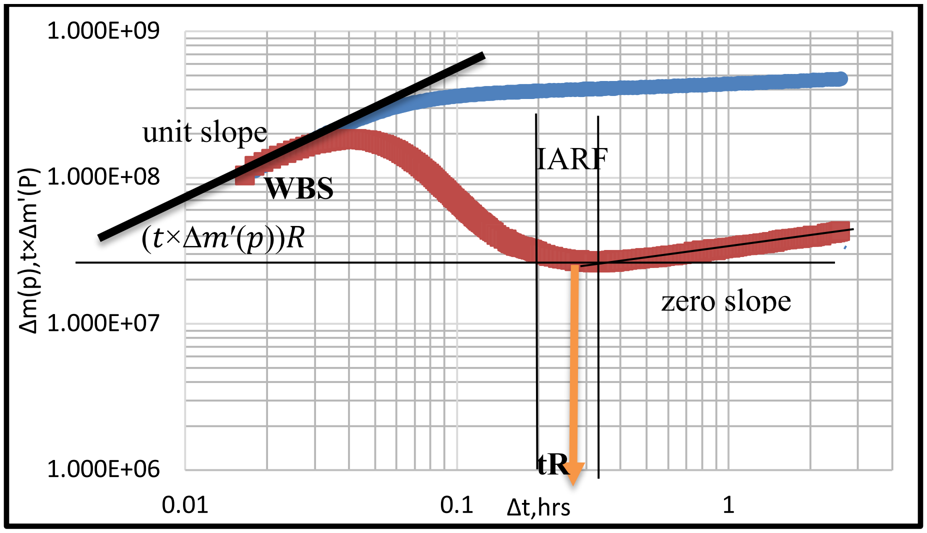

Figure 5: *Analysis of infinite acting radial flow for Well (5A5).*

3.2.2 Infinite acting radial flow line is not observed (short test) for Well (5A5):

In this case, the infinity acting radial flow line was cut to apply the analysis (short test) when infinite acting radial flow is not observed as shown in figure 6. From figure 6 read the value of tx, and (t×Δm'(P)x) and calculate $(t\times\Delta m'(P))_R$ using equation 8.

$$(t\times\Delta m'(P))R = \left(0.151\frac{24.05\times10^3\times(240+460)}{0.0282\times0.0402}\right)\times0.069-1.29\times10^8$$

$= 2.67\times10^7$ psi^2/cp.

Calculate the permeability from equation 5.

$$K = \frac{711.26\times15.807\times10^3\times(263+460)}{31\times2.67\times10^7} = 6.88 \text{ md.}$$

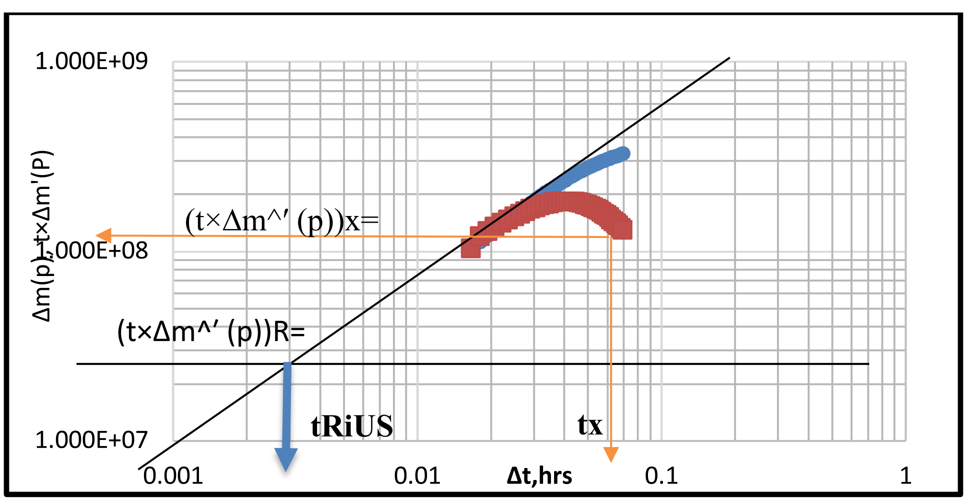

Figure 6: *Short test for Well (5A5).*

Read the value of tRiUS (tRiUS=0.043 hrs) from figure3. , then calculate total skin factor using equation 9.

$$S' = 0.171\left(\frac{0.069}{0.043}\right)^{1.24} - 0.5ln\left(\frac{0.8935\times0.0402}{0.139\times33.5\times1.13\times10^{-4}\times0.34^{2}}\right) = 2.15$$

3.3 Summary of the Results:

Table 5 shows the comparing of the main results between the long test and short test in Wells.

Table 5: *Comparing the results of Well (4U11) and (5A5).*

Parameter	Well 4U11	
	Long test	Short test
(t×Δm' (p))R,psi²/cp	2.68×10^{7}	3.67×10^{7}
K,md	13.33	13.35
Total skin(S')	2.15	2.15
	Well 5A5	
	Long test	Short test
(t×Δm' (p))R,psi²/cp	4×10^{7}	3.81×10^{7}
K,md	6.55	6.88
Total skin(S')	15.64	16.75

4 Conclusions

Based on the results, TDS technique was shown to be useful, accurate and effective. The technique is particularly useful when the infinite acting radial flow or wellbore storage line have not been observed. The TDS method showed accurate results compared to conventional software matching, the values of permeability by using (Long test) was 6.55 md in Well (4U11),13.33 md in Well (5A5, where the values of permeability by using(Short test) was 6.88 md in Well (4U11),13.35 md in Well (5A5, and the value of total skin factor using (Long test) was 15.64 in Well (4U11) ,2.15 in Well (5A5), where the value of total skin factor using (Short test) was 16.75 in Well (4U11) ,2.15 in Well (5A5). The TDS is an effective method for calculating the average reservoir pressure from well test data for a vertical gas wells, where the average reservoir pressure was (6656) psi in Well (4U11) and (4991) psi in Well (5A5).

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